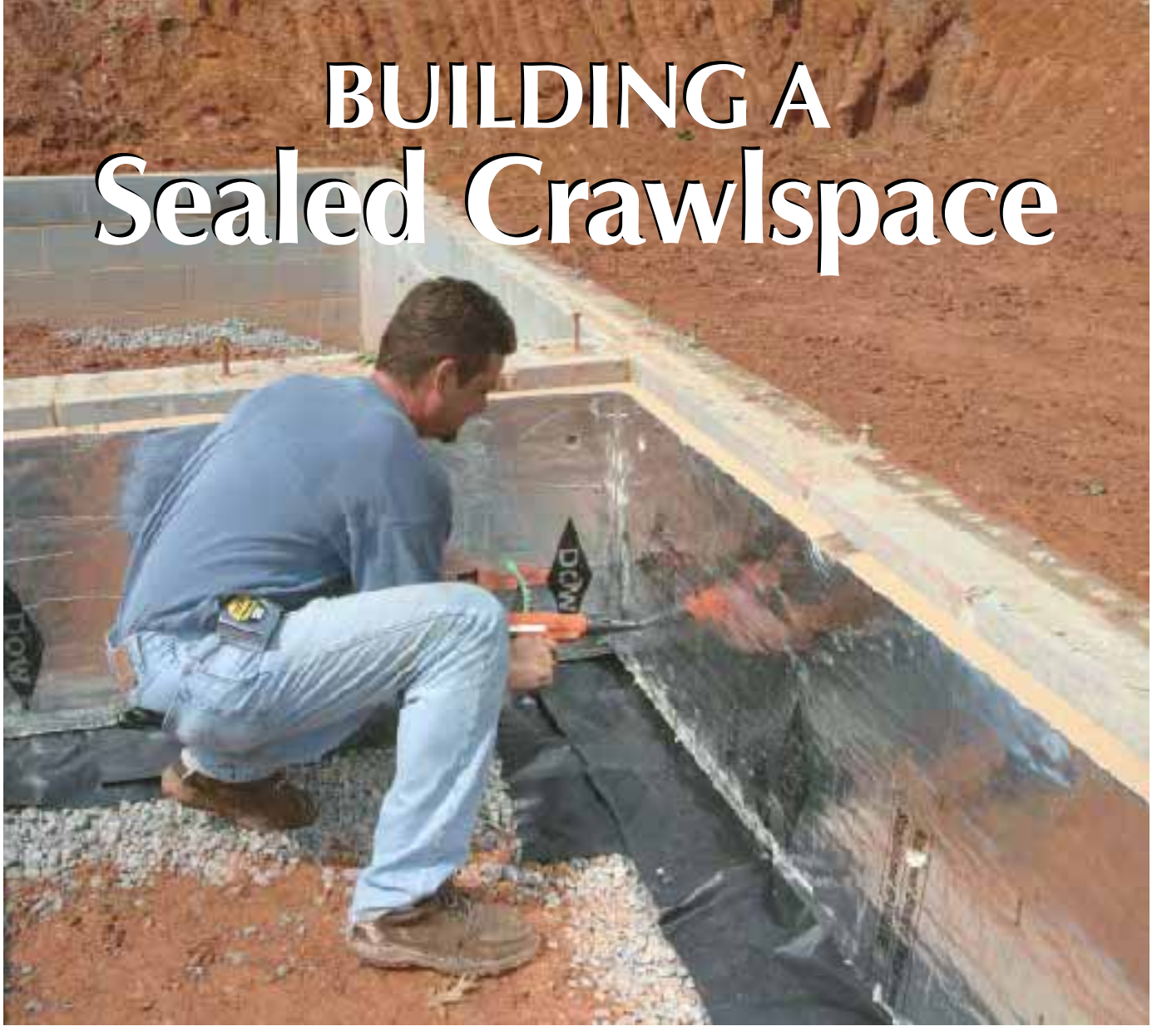
# BUILDING A Sealed Crawlspace



Good drainage, a continuous poly liner, and a supply of conditioned air will keep the crawlspace as dry as the rest of the house

by Jeff Tooley

Recent research provides plenty of evidence that vents for crawlspaces don't work, and that sealed and conditioned crawlspaces are a better choice. But my business, the Healthy Building Company, is the first I know of to specialize in applying that science in the field. We've been sealing up crawlspaces in houses with moisture and mold problems for five years, and we're taking on an increasing volume of work building dry crawlspaces for new homes.

We've developed a set of simple, effective, and repeatable methods that produce predictable results. In this article, I'll describe what they are, and how we deal with various obstacles that may crop up along the way.

In general, our installations have four phases. The first is the builder's job: Waterproof the foundation and install good foundation drains. Next, we come in and apply poly and rigid foam insulation to the foundation walls. As soon as there's a roof on

so that rain won't get into the crawlspace, we come back a second time and put down a sacrificial layer of poly to keep the ground vapor out for as long as it takes to finish the house. Then, in the final two weeks of the job, we come back to take out this temporary "construction poly" and install a permanent version, carefully sealed at all seams and secured to the ground. At the same time, we also install a quiet ventilation fan that runs continuously to provide the newly sealed space with a steady supply of conditioned air.

## Managing Bulk Water

My vapor barriers are sealed with mastic, and they're both watertight and airtight as well as vapor-tight. But I don't intend them to cope with pressure from groundwater. Since I work as a sub on the job, I hold the builder totally responsible for managing bulk water. I tell him that if he lets groundwater come up under my poly, presenting the risk of flooding the crawlspace, then I won't guarantee the results. Our mastic joints are very tough, but they can fail under pressure. One good rip in the poly, and bulk water intrusion could completely bypass our vapor barrier.

So I need to see waterproofing, or at least dampproofing, on the foundation walls starting at the finish grade and extending down to the footing. I want a perimeter drain at the level of the footing, sloped to one corner of the building (see Figure 1). An exterior footing drain is the minimum; even better is to have drains on both sides of the footing, connected across the footing at the low corner.

The crawlspace floor is also sloped to that low corner, so that if a pipe breaks and floods the space, water will drain that way on our poly. To provide the water with an escape route, we install a backwater valve in that low corner (Figure 2). The valve is connected to the perimeter drains; when we later install the final poly, we cover the inlet with a grate that's sealed to the poly with mastic. When the crawlspace is dry, the valve stays closed and keeps the groundwater out. But if water collects in the corner of the crawlspace, the valve flapper opens and allows the water to drain out through the footing drain. You can get these from your local plumbing supply or from D.A. Fehr, a distributor of plumbing supplies (800/325-8999, www.dafehr.com/Canplas/cisbwvalvefeat.htm).

**Figure 1.** Perimeter drains around the foundation footing are necessary to prevent bulk water from threatening the crawlspace's poly vapor barrier or its mastic-sealed seams.

**Figure 2.** Managing bulk water is essential for success in a sealed crawlspace. The author ties a backwater valve into the foundation drain system at the low spot in the crawlspace, so that any water from a plumbing leak will be able to drain out through the perimeter drain.

The crawlspace floor isn't usually graded perfectly smooth. In the event of a flood caused by a plumbing leak, little dips and hollows might collect puddles, but that much water can evaporate out without wrecking our crawlspace. What we're trying to avoid is 10 inches of standing water, and this setup does it.

***Complete dampproofing.*** The North Carolina code calls for dampproofing only where the exterior grade is higher than the interior crawlspace floor. This means that if I have a 4-foot block wall with 2 feet of earth inside it and 3 feet backfilled against the outside, dampproofing is required only on the 1-foot portion where the exterior soil is higher than the interior soil, not all the way to the footing. This seems to assume that water won't come through a block wall if there is soil on the other side. I don't see anything to prevent it, so I say use the belt *and* the suspenders: Coat the foundation all the way to the footing, and install drains inside and out.

## Wall Poly and Insulation

Once the builder has the foundation wall built and the drainage installed, I install the poly and foam on the inside face of the wall. We attach the 6-mil black plastic to the wall with a water-based adhesive mastic (Figure 3), then fasten the foam board over it with powder-driven masonry nails (Figure 4, next page). The wall poly extends onto the ground about a foot, leaving an edge flap for us to seal the floor poly to later.

***No batts in the floor.*** Under the energy code, insulating the foundation to R-10 means we don't have to insulate the floor under the living space. We get rid of the usual fiberglass batts in the joist bays, where their performance is hindered anyway by air movement, poor fit, and interruption by wires, pipes, and bridging; and we locate the thermal boundary of the house with the air-pressure boundary where it should be. People concerned about indoor air quality are glad to see the fiberglass go, because it means no irritating fibers will be floating around to get sucked into the ductwork.

***Sidewall penetrations.*** Where pipes or wires go through the side wall, we have to fit the foam board to them carefully and seal the vapor barrier around them (Figure 5, page 5). I'm working right now on a lot of houses with package heat pump units, which add another large penetration for us to fuss with.

Detailing the duct penetration is just patchwork. Where the builder runs flex

**Figure 3.** The author brushes mastic onto the block wall (right), then applies 6-mil black poly (below). Mastic creates a strong adhesive seal on many different materials, even if the surfaces are dirty.

duct from the unit through the wall, we have to cut a half circle on one piece of foam board and a half circle on the other, then piece them together around the duct and seal the joint.

We use a water-based, nontoxic duct-sealing mastic called PS-1, from RCD Corporation (800/854-7494, www.rcdcorp.com), for all our sealing work because it is so effective. It sticks to all kinds of materials, rough or smooth, and even to dirty surfaces. It dries in hours and is tough and strong; once a mastic joint in poly sets up for real, two men can't pull it apart with all their strength.

## Sealing the Floor

We install our sacrificial floor poly as soon as the house is dried in. Once the house is enclosed, vapor that enters the crawlspace will start to accumulate, so delaying this step can spell big trouble.

For example, I was called earlier this year by a builder who wanted me to seal up his crawlspace, but it soon became clear that he had built his foundation almost a year earlier with no vents, ground vapor barrier, or wall poly. "What's it like down there now?" I asked him. "I don't know," he said. "I haven't looked."

A lot of bad things can happen in ten months in a sealed crawlspace with no vapor barrier and no conditioned air supply — and in this case, they had. When I took a look, I found the floor joists covered in a thick fur of white fungus filaments. It wasn't mold, but the kind of rot you find under dead trees in the woods. This type of decay can seriously weaken wood before it's even visible. The necessary fix might go well beyond a simple cleanup.

Mold will grow on surfaces at 70% relative humidity, but wood rot means that the framing was saturated from long exposure to 90% or higher relative humidity. Vented crawlspaces don't usually get that damp, but an unvented one with no ground cover can. That's why it is so crucial to get your construction poly in place at the earliest possible moment. Without it, your whole project is at risk.

***Installing the sacrificial poly.*** We place temporary ground poly as soon as there is tar paper on the roof. We lay the sheet out to completely cover the floor area, but without sealing the seams. We use the same poly for the temporary cover as for the permanent installation — it's just the 6-mil all-purpose black plastic sheeting that you can pick up at any building supply outlet in 50-foot or 100-foot rolls, in widths of 15, 20, or 24 feet.

***Drying the framing.*** The temporary ground cover prevents soil moisture from evaporating into the crawlspace. But by the time the poly goes down, the floor framing may already have absorbed quite a bit of moisture from the soil beneath and from rain falling on the still unroofed structure. To promote rapid drying, we temporarily

**Figure 4.** The author attaches foam board to the foundation wall using powder-actuated nails (five nails per piece of foam). Although some building departments have required foil-faced polyisocyanurate foam (top), he generally uses extruded polystyrene (bottom). Either way, the R-10 foundation insulation meets the energy code without the need to insulate floor cavities with fiberglass. But air sealing and vapor sealing, not insulation, are the main reasons sealed crawlspaces reduce the load on the hvac system.

install a small dehumidifier in the crawlspace at the same time we install the poly. So we don't have to count on anyone remembering to dump the reservoir, we rig the drain tube so it discharges outside the crawlspace.

Dehumidifiers are rated on the basis of cubic footage, and most crawlspaces are low enough in volume to make a large unit unnecessary. We use a 25-pint model made by Whirlpool for most of our houses. The dehumidifier stays in place until we remove the sacrificial poly and replace it with the permanent, sealed ground covering — anywhere from a few weeks to several months, depending on the construction schedule.

***Permanent floor covering.*** A week or two before the house is ready for the owners to move in, we take out the temporary poly and put down a nice, clean final floor.

By this time the construction poly has generally been damaged and disturbed by the mechanical subs and other people who have been working in the space. I suppose we could just cover it up with the new poly, but it's better to take it out because it's almost always sprinkled with chunks of wood, sawdust, cardboard, and other scraps. We just bundle all that termite bait into the poly and haul the whole mess out. It's a quick cleanup.

**Figure 5.** The author carefully fits poly around a pipe that runs through the foundation wall, then seals the poly to the pipe with mastic. All penetrations through the crawlspace wall must be sealed.

**Figure 6.** After removing the temporary poly, the author rolls out a new layer of 6-mil poly, carefully sealing the seams with duct tape and mastic (above). He also makes a duct tape and mastic seal where the poly laps up onto piers (above right) and around the grate that covers the backwater-valve floor drain (right).

***Lapping and sealing.*** Then we place the new permanent poly floor covering, sealing the seams at the wall poly with duct tape and mastic, and also sealing every joint in the field (Figure 6). Each joint is secured with duct tape that is then coated with a brushed-on layer of mastic. The stripe of mastic extends at least an inch beyond the tape on each side.

It matters how you lap the poly at joints: You need to create a shingle effect to handle flowing water, but you're shingling upside down. You're placing poly on a slope, and water will run down the ground surface beneath the poly. If you lap the joint one way, it will allow the water to flow past, but if you lap it the other way, the lap will scoop water and hold it against the seam, threatening your mastic seal (Figure 7, next page). It's a small thing that matters — mastic handles incidental water beautifully, but like any material, it may not perform so well if you let it get continuously soaked.

***Floor spikes.*** To make sure the ground cover lasts and stays put, we nail the poly to the underlying soil with 6-inch spikes and washers (Figure 8, page 7). We use a lot of spikes — 5 to 10 per 100 square feet of poly — but it's well worth the time and effort. Imagine a worker in the crawlspace dragging a tool box along. If the corner of the box snags on the poly and the poly is not secured, he could pull out most of the ground cover at one time. If it's nailed down, he might rip a 10-foot piece off, but the rest of it would stay intact.

In case of accidents like that, we

always leave behind a patch kit consisting of a 250-square-foot piece of poly, a roll of tape, a brush, and a gallon of mastic. The homeowner can fix 250 square feet with our kit by simply laying down some poly, fastening it with tape, and brushing mastic over the tape.

***Preventing future damage.*** To protect the permanent poly, we lay carpet runners in the space as a path for service technicians, running from the access door to the water heater, furnace, and any other appliance (Figure 9). One of the builders I'm working with right now doesn't put any equipment in the crawlspace; for that company, we just set a 10x10-foot square of carpet right inside the access door, in case the homeowners want to store something.

Some builders like to make crawlspace storage a selling point, but our crawlspace is virtually inside the house — it's just like the family's living room, and they have to treat it that way. That means the builder has to inform the homeowners that they can't store lawnmowers, pesticides, fuel, and the like in their sealed crawlspace.

## Ventilation and System Monitoring

At this point, the crawlspace is clean, dry, well insulated, and both airtight and vapor-tight. All that's missing is a

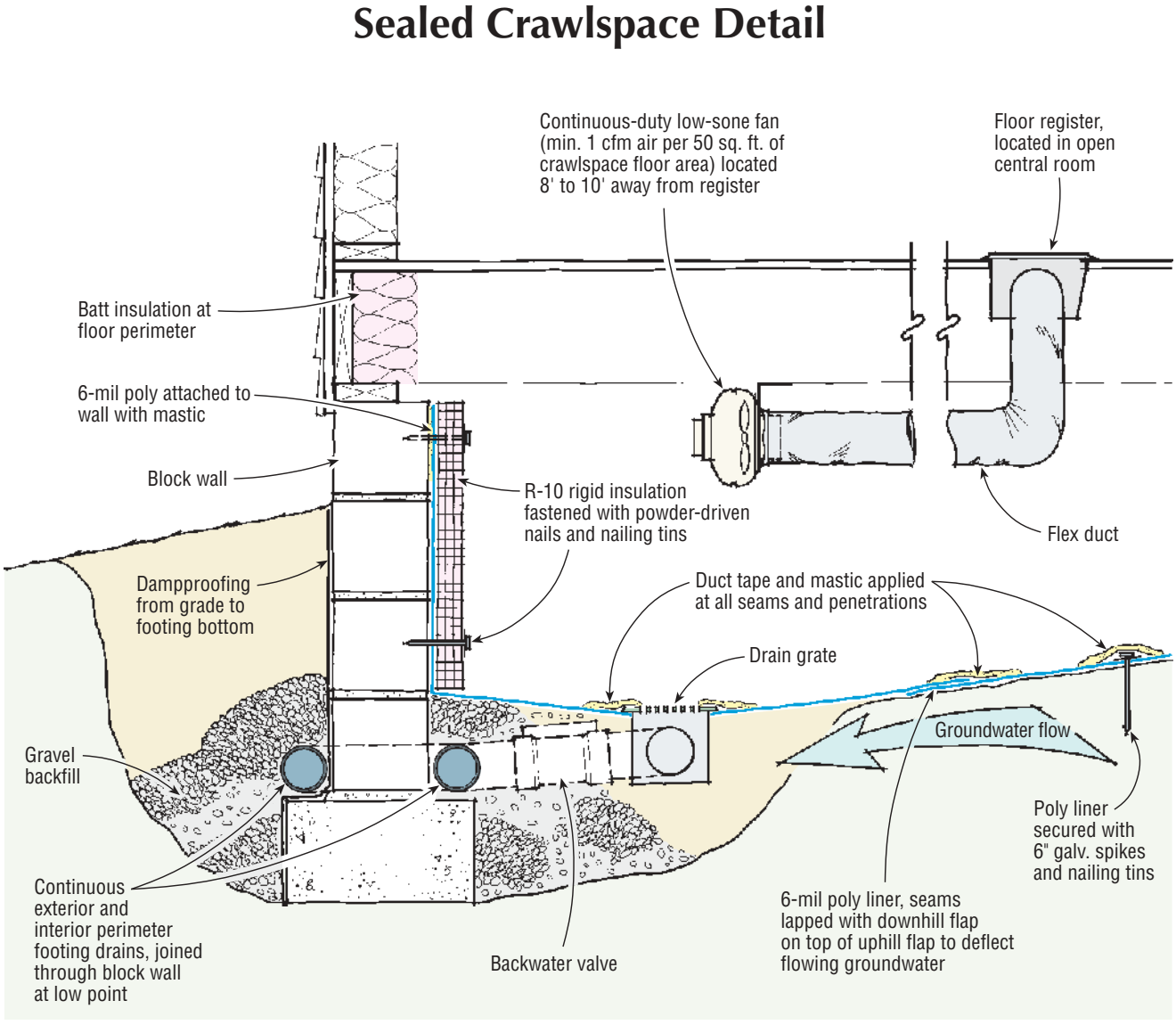



**Figure 7.** The components of a sealed crawlspace must address the issues of bulk water, air sealing, vapor sealing, and thermal insulation. Dampproofing and perimeter drains are necessary details, because the poly ground cover is not designed to handle constant water contact. The author prefers drains both inside and outside the footing, joined at the low point. He ties a floor grate into the interior footing drain and protects the link with a backflow preventer valve. Floor poly is lapped reverse-shingle fashion so as to manage water flowing in the soil beneath the plastic. For maximum resistance to air and vapor infiltration, seams in the poly and at penetrations are sealed with mastic. R-10 insulation is placed at the foundation wall, aligning the air, vapor, and thermal boundaries of the space in the same plane. Finally, the fan ventilates the space with conditioned house air.

steady supply of conditioned air. Builders always expect me to install the fan, but, unfortunately, my hands are tied. Although installing a ventilation fan is a simple job, my state won't let me do it because I'm not a licensed mechanical contractor.

***Ducted fan.*** We do recommend a specific approach to ventilation that we've found to work well. We first install a floor register in an open central room that can't be closed off from the main body of the house (this prevents our fan from having to compete with the home's hvac system). We have the mechanical contractor place a continuous-duty low-sone fan under the floor about 8 or 10 feet away. Vent and fan are then connected with a run of flex duct (Figure 10). Separating the register and the fan in this way makes for quieter operation.

Our remote fan setup under the floor isn't the only way to provide ventilation. You could also locate the fan in

**Figure 8.** The author secures poly to the floor with 6-inch galvanized spikes through nailing tins (above left). He then applies duct tape and mastic over the tin for reinforcement and a tight seal (above right).


**Figure 9.** The author installs carpet runners over the poly as a pathway for tradesmen servicing basement appliances (above). He posts a sign warning workers not to rip the poly (right), but he also leaves a patch kit in case the poly does get damaged.

**Figure 10.** A quiet fan placed in the crawlspace runs continuously, drawing air from the main living space through a floor register and a short run of flex duct. The steady supply of conditioned air maintains the crawlspace at a humidity close to that of the main house.

the above-floor room and duct it to the crawlspace through a stud bay, for example. The code doesn't specify this detail one way or the other. Code officials make various judgment calls on the forced-air supply to crawlspaces. Some North Carolina municipalities, for example, now require an air-conditioning supply register for the crawlspace; a dedicated fan is not considered acceptable. Where I've been working, it's the other way around — the fan's okay, but not a duct register.

In reality, it probably doesn't matter much either way. Fan or no fan, there's going to be constant air movement between the crawlspace and the rooms above. I've seen this countless times in houses with moisture problems. Humidity readings in upstairs rooms are always virtually the same as in the crawlspace.

***Monitoring humidity.*** When we've finished sealing a crawlspace, we install a humidity sensor under the floor; the sensor is wired to a digital readout and alarm located upstairs. Homeowners tell us the readout tends to settle at a relative humidity of around 50% to 55%. Mold starts to grow at around 70% relative humidity, so we set the alarm close to the top of the safe range, at about 65%. This prevents nuisance alarms when the whole family gets together at Thanksgiving and spends the day cooking, temporarily causing the indoor humidity (including that of the crawlspace) to spike.

We've yet to hear of an alarm going off at that 65% threshold, which seems to confirm that sealed crawlspaces do control moisture. The state of the floor framing is another good indicator. While the normal moisture content of joists in a vented crawlspace is around 16% to 18%, ours are running at 10% to 12%.

## Costs and Benefits

My company is currently charging production builders about $1.75 per square foot to seal up a crawlspace, including materials. Custom builders pay more like $1.95. But there are offsetting reductions in other construction costs.

***Up-front offsets.*** First of all, my price includes insulating the foundation walls, so you can subtract the cost of the floor insulation you don't have to put in. That's 40¢ per square foot in our market. So from $1.75, you're now closer to $1.25. You can subtract the cost of buying and installing foundation vents, as well.

Also, by sealing the crawlspace, we cut the heating and cooling load on a house substantially. This has an especially pronounced effect on the air-conditioning load, because dehumidification accounts for much of the work an air conditioner has to do in our area. By eliminating all the soil moisture and a big chunk of the infiltrating humid air, we drastically reduce that latent cooling load. On an

## Planning for an Unvented Crawlspace

When you change from an accepted method to an alternative one, building inspectors don't automatically climb on for the ride. Building officials are often uncomfortable about sealed crawlspaces because the code doesn't address them in any detail (see "Sealed Crawlspaces and the Code," next page). If you don't explain the details to the building department in advance, inspectors may be uncertain how to evaluate your work when they see it — and may even suspect that you're trying to sneak something past them.

That can lead to expensive and unnecessary problems. On one of our jobs, the inspectors made me install horizontal perimeter insulation below grade, as if I were building a frost-protected shallow foundation. It never freezes where we work — they were just mad at me. In another case, a half-million-dollar project was held up for 45 days while the building department investigated, delaying the closing for two weeks.

So I've learned to prepare the groundwork. Right from the start, I make sure that the owner, builder, and code officials know what my intentions are and what I expect from them.

***Step by step.*** We do that by handing everyone involved some simple, clear documents. The builder gets a detailed process outline that explains exactly what's going to happen and when. In effect, it says, "You're going to call us within a week or two of putting up the foundation wall, and we'll come put poly and foam board on the wall. As soon as you have tarpaper on the roof, you'll call us again, and we'll come put down some construction poly." The script spells out each step and takes the builder right to the end of the job. We also stress the importance of making the sealed crawlspace part of the original permit application so the building department knows what to expect.

***Inspection guidelines.*** We also have a one-page detail sheet that the building department can use to inspect our work. This document provides plenty of specific information, down to the five mechanical fasteners per sheet of foam board. We try not to leave them guessing about anything.

Even though some building departments decide to apply some different requirements after considering our detail sheet, it at least serves as a solid starting point. The detail sheet itself is backed by a letter from an engineer, which endorses all the specifications contained in it.

average house, our work lets you downsize the equipment by 1/2 to 1 ton of cooling and reduce the ductwork accordingly. By the time you add up those direct offsets, our crawlspace work is almost free.

***Callbacks and customer satisfaction.*** That reduction in load translates to lower energy bills for the homeowner, year in and year out. But the builder also gets a long-run benefit: Houses with sealed crawlspaces are much more stable from season to season, which means that some of the callback money you now spend caulking trim joints or rehanging doors will stay in your pocket.

Finally, there's liability. As anyone who's spent some time in a crawlspace knows, conventional vented crawlspaces are often musty and moldy. A well-sealed crawlspace, on the other hand, typically contains less mold than the outside air. In today's legal climate, that's no guarantee that you won't get sued anyway, but it can't hurt.

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## Sealed Crawlspaces and the Code

The *International Residential Code* is less than crystal clear about how to detail an unvented crawlspace. The main text requires vents of a calculated size in all crawlspace walls. Ventless crawlspaces are allowed under two different exceptions, both of which require some additional interpretation.

***Taking exception.*** The first of these, Exception 4, says vents can be eliminated if continuous mechanical ventilation is provided at a rate of 1 cfm per 50 square feet of crawlspace floor area, but it doesn't say where the air has to come from or mention insulation. The second, Exception 5, says that vents aren't required as long as the space is supplied with conditioned air. How much air, though, and how it should be delivered, is not specified. Unlike Exception 4, Exception 5 does call for insulation of the perimeter walls to meet the energy code.

There's a lot of room in that language to make mistakes. In our hot, humid climate, we definitely don't want a continuous ventilation fan to pull in outside air. And we don't want it to pull air from the crawlspace and push it outdoors, either, because that would depressurize the crawlspace and draw moist outdoor air in through cracks and seams. Any fan you install should take air from the house and add it to the crawlspace.

In theory, that will slightly pressurize the crawlspace and cause air to move away from the crawlspace in all directions. Whether or not the crawlspace becomes pressurized in practice depends on a variety of factors, including wind pressure and the tightness of the subfloor and ductwork.

In practice, subfloors in real homes are so full of holes, and ductwork located in crawlspaces is typically so leaky, that the uncontrolled air exchange between the crawlspace and the house far exceeds the amount moved by our fan. The fan is not really necessary, as I know from all the existing crawlspaces I've fixed without one. But bringing conditioned air below the floor is the right idea, and it can't hurt. I like the belt-and-suspenders approach, as I said, so I don't mind the fan.

***Basement or bedroom?*** Our application actually satisfies the provisions of both exceptions: We provide the 1 cfm of continuous ventilation required under Exception 4, and we do it with conditioned air, as required under Exception 5.

But that brings up another potential problem. Once you've conditioned the crawlspace, the code people aren't sure how to treat it. Some of them want to call it a plenum, while others want to consider it habitable space, like an additional bedroom. Either way, exposed wiring and plumbing can be an issue, even though there's no sensible way to cover those elements up inside a crawlspace.

Fortunately, most code people end up willing to think of our crawlspace as a very short basement. They've seen regular basements with all the same details, and they haven't treated them as habitable space.

***Paddling into the mainstream.*** We still run into problems occasionally. For example, I've been using extruded polystyrene rigid insulation on crawlspace walls for years, but on one current project the building department decided that since the space is conditioned, we couldn't leave that foam exposed. We had to switch to foil-faced polyisocyanurate, which isn't used much in our area and had to be specially ordered.

But we find that when we make the effort to educate and inform code officials in advance, most of them can relate to what we're doing. Our engineer's letter reassures them that they won't be blamed if something goes wrong.

Finally, we have one big thing going for us: What we're doing works. When building inspectors compare our dry, clean crawlspaces to the dank, moldy pits under most houses, it's hard for them to complain. Over time, they're going to start taking our methods for granted.